SASKATCHEWAN RESEARCH COUNCIL

AN ATMOSPHERIC CARBON DIOXIDE REVIEW AND CONSIDERATION OF THE MEAN ANNUAL TEMPERATURE TREND AT SASKATOON, SASKATCHEWAN

by

S.R. Shewchuk

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TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
	1.1 Atmospheric carbon dioxide	1
	1.2 Carbon dioxide variation	5
	1.3 Modelling the carbon dioxide effect	7
	1.4 A recent trend	9
2.	PROCEDURES	11
3.	RESULTS	13
4.	DISCUSSION	20
	4.1 The atmospheric carbon dioxide effect	20
	4.2 Climate trends at CRS	21
5.	REFERENCES	23
APPENDIX		25

LIST OF TABLES

		Page
Table 1.	Mean annual temperature for 20 years of record at CRS.	13
Table 2.	Semi-averaged mean monthly temperature data from CRS for the 1964 to 1983 period	17
Table 3.	Mean temperatures, standard deviations and calculated student's t statistic for several periods between the two decades of record	18

LIST OF FIGURES

Page

Figure 1. Mean annual temperature vs year. The dashed curve is the semi-averaged line. 14

Figure 2. Five-year running means for the annual temperature at CRS 15

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SUMMARY

A description of atmospheric carbon dioxide, its sources, sinks and distributions were discussed in this report. It appears that anthropogenic influences are having a measurable impact upon atmospheric concentrations of carbon dioxide. Several research workers have attempted to model the effect of the build-up on global climate. It is generally recognized that increasing carbon dioxide will cause a gradual climatic warming. Signs of climate warming trends are currently being shown in the polar regions of the globe.

Twenty years of record are available for the Climatological Reference Station of the Saskatchewan Research Council. The mean annual temperatures were considered for this time series and various climatic trends identified. Both the annual mean temperatures and the five-year running mean of annual temperature showed a gradual increase of temperature with time. The "semi-average" data, both on the annual and the monthly air temperature, show a climatic warming trend in progress. The temperature increase between the first decade (1964-1973) of the study and the last decade (1974-1983) is 0.5°C. Nine of the twelve months showed a warming trend in the last decade, with the winters becoming significantly warmer. This is in line with other evidence suggesting a warming trend for the Northern Hemisphere. However, statistical techniques applied to the "semi-averaged" curves did not confirm the significance of a trend at the five percent probability level. The coolest year of the record period was 1982. This coincides with data from other observers who report 1982 as being particularly cool. Most attribute the cooling to the volcanic dust emitted into the stratosphere by the volcano El Chichon.

1. INTRODUCTION

1.1 Atmospheric Carbon Dioxide

An aspect of our modern day society is that through technological intrusions into the earth's environment we are inadvertently influencing many of its natural processes. It is therefore crucial that we obtain a clear understanding of the effect of these man-induced forcing functions upon the environment. The combustion of fossil fuels is returning to the atmosphere and ocean the concentrated organic carbon which had been stored in sedimentary rock for hundreds of millions of years. On a geologic time scale this means that we are forcing an extremely violent transient upon the earth-atmosphere system.

Carbon dioxide (CO_2) is a gas which makes up approximately 0.03% by volume uniform distribution throughout the atmosphere. It is a very important part of the carbon cycle, which is so necessary for the existence of life on this planet. Since it has an important absorption band in the range 13-17μ, it is a component of the earth-atmosphere radiation balance, and therefore has an influence on the thermal regimes of the earth-atmosphere system. It is generally believed that large increases of this gas in the atmosphere could significantly increase surface temperatures.

Carbon dioxide is a conservative property of the air, its distribution is unaffected by temperature or rainfall variations. In this sense then, it is a very promising trace constituent for understanding atmospheric mixing processes on a global scale. Observed variations of atmospheric CO_2 with season, latitude and altitude are the result of sources and sinks which exist only at the earth's surface. These sources and sinks are responsible for regular variations in CO_2 in the lowest layers

of the atmosphere. The penetration of CO_2 upward and horizontally in the atmosphere can yield quantitative information about the transfer mechanisms of the atmosphere.

Atmospheric CO_2 serves as a carbon source for the synthesis of organic compounds in photosynthesizing plants. Animals must depend upon the plants for their organic compounds. Chemical changes in organic compounds may occur to keep carbon trapped within organic compounds, and some carbon may be lost to the cycle for long periods of time. Coal and oil deposits were formed many millions of years ago from plant and animal bodies, and the carbon is not available to the atmosphere until these materials are burned. Eventually this carbon is returned to the atmosphere in the form of carbon dioxide. Carbon can also return to the cycle within a much shorter period through respiration of plants and animals and through processes of decomposition. Although of limited importance in a quantitative sense, volcanic eruptions also contribute carbon dioxide to the atmosphere.

Plass (1956-A) has calculated the amounts of carbon dioxide involved in each portion of the carbon cycle. He has concluded that the organic and inorganic worlds are approximately in a balance. In addition, he contends that man's influence is large enough to upset the CO_2 balance in nature. The concentration from this source, he states, is increasing at a rate of about 30% per century.

An interesting mathematical model of the carbon cycle in nature has been considered by Eriksson and Welander (1956). The authors suggest that even if the CO_2 content of the atmosphere is increasing, it may not be due to the CO_2 from combustion of fossil fuel. In the natural carbon

cycle there may appear oscillations which are not generated by external forces, but originate or are sustained within the system. These authors suggest that most of the fossil fuel carbon will either be assimilated by the biosphere or absorbed into the ocean surface, and not go to the atmosphere.

Carbon dioxide can be absorbed into a very shallow layer of the ocean surface. In a classic paper Callender in 1938 has calculated that about 1.3% of the whole volume quickly reaches equilibrium with the atmosphere. If the amount of carbon dioxide in the atmosphere were to suddenly change, the time to reach a new equilibrium of carbon dioxide between the atmosphere and the ocean would be in the order of the turn-over time for the vertical circulations of the oceans, which is about 10,000 years. The oceans are therefore not efficient sinks for CO_2.

Dingle (1954) has found that air masses which have their source region over the warm tropical oceans (i.e., maritime tropical air, mT) show a higher content of CO_2 than the air masses whose source region is the mid-latitude ocean areas (i.e., maritime polar air masses, mP). This illustrates that there are distinct source areas on the earth's surface for CO_2.

From the results of Keeling et al. (1976) it is quite clear that the CO_2 content of the atmosphere is increasing. Since CO_2 has important absorption bands for terrestrial radiation, it becomes important to inquire whether or not this increase is having an effect on climate. From Mitchel's (1970) curves it is clear that the earth's average temperature has undergone a small increase of 0.6°C in the period 1880 to 1940, while after 1940 there has been a decrease in the mean surface temperature of

the earth of 0.3°C. In southern Saskatchewan, a recent analysis by Magill (1980) showed that up to the period of 1970 a predominant cooling trend was evident in the mean annual temperatures. The cooling influences which research scientists today suspect as important are likely either particulate dust or a natural secular cycle. The dust increases have been affected by industrialization, cultivating lands, burning of tropical vegetation and an upsurge of volcanic activity since 1948. The cooling effect of dust results from the scattering of radiation and from an augmented mid-tropospheric infrared flux divergence.

It should be noted that the carbon dioxide effect is not the only extrinsic modifier of our global climate. Bryson in 1974 outlined the main extrinsic controls on climate. These are:

1. the solar constant
2. transmittance of radiation through the atmosphere
3. the albedo of the earth-atmosphere
4. The carbon dioxide control of infrared fluxes.

It is only the last of these four controls that is considered in this report.

1.2 Carbon Dioxide Variation

The carbon dioxide content of the atmosphere is a very sensitive function of the surface exchange mechanisms. Thus we should expect seasonal variation and even diurnal variation in the gaseous constituent.

The variation of CO_2 over a land surface has been considered by Lieth (1976) to be due to a production unit on the earth's surface which is primarily the land vegetation. He concludes that not only is the plant community a product of the environment, but it also, by its presence, exerts an infuence on that environment. The CO_2 content near the ground can be changed very effectively by the plant community. If the plant community were to fix the atmospheric CO_2, it could be depleted in about 25 years.

The variation of CO_2 over a land surface has been considered by Fonselius, et al. (1956). They measured the CO_2 content of the atmosphere over Scandinavia by the flask method (see Tanaka et al. 1983) of measurement. The concentration near the ground was found to average about 320 p.p.m. by volume. This value represents a slight increase over that from the late nineteenth century measurements. They also observed air mass variation and seasonal variation of CO_2. There was a striking difference in the CO_2 content of the atmosphere in Finland whenever warm continental air from Russia or maritime arctic air from Sweden or Norway prevailed. Their values also showed that the mean monthly values were highest during the winter months with a steady decrease during the spring to a low value in the summer months, and finally, to increases in the autumn. This is quite clearly the effect which has been produced by vegetation, it has maximum assimilation in the summer.

A measurement of the trend of CO_2 in the atmosphere has been obtained by Brown and Keeling (1965). They used the infrared gas analyser method of measuring CO_2 content over Hawaii. At both of these stations they found that there was a yearly increase in the CO_2 content of 0.7 p.p.m. per year. They concluded that this consistent increase leaves little doubt that there is an average global increase of CO_2. In addition, the Hawaii study showed an annual amplitude variation of 6 p.p.m. in the seasonal variation.

Bolin and Keeling (1963) discuss a model for the global variation of CO_2. Using simple features to describe the large scale meridional exchange processes of the atmosphere, they conclude that the northern hemisphere is a considerably larger source of CO_2 to the atmosphere than the southern hemisphere. In addition they concluded that much of the observed larger atmospheric concentration of CO_2 in the Northern Hemisphere can be accounted for by the greater land biomass and greater industrial emission.

1.3 Modelling the Carbon Dioxide Effect

Callender (1938), was one of the first twentieth century authors to revive the old nineteenth century theory of CO_2 variation causing climatic change, which was originally abandoned when it was found that all long-wave radiation absorbed by CO_2 was also absorbed by water vapour. But now several factors suggest that water vapour has a lesser effect. The mixing ratio of water vapour decreases very rapidly with height, while the mixing ratio of CO_2 is very nearly constant with height. Hence water vapour controls the radiative flux for only a relatively short distance above the earth. Plass (1965-B) has calculated the upward and downward radiation fluxes and the cooling rates for the 15μ band of CO_2. His results indicate that the average temperature of the surface of the earth would increase 3.6°C for a change of concentration from 300 p.p.m. to 600 p.p.m., and that it would fall 3.8°C if the CO_2 concentration drops from 300 p.p.m. to 150 p.p.m. But the crucial assumption he made was that nothing else changed that could affect the radiation balance.

Möller (1963) has more realistically included the effect of overlapping adsorption bands of CO_2 and H_2O in the range of 15μ. He found that when the present CO_2 content is doubled (from 300 p.p.m. to 600 p.p.m.) the temperature decreased 1.5°C. He further suggested that for a small increase of CO_2 (from 300 p.p.m. to 330 p.p.m.) certain mechanisms are in effect which will negate any temperature increase. For instance, the temperature effect in the latter case could be completely compensated for by a 3% change in water vapour or a 1% change in cloudiness.

It is clear that any change in the earth's radiation budget will be

affected by alterations in the entire heat budget of the surface. Heat consumption by evapotranspiration and transfer of sensible heat to the atmosphere will be changed. Also the water vapour content, vertical lapse rate of temperature and cloudiness will all be changed.

A theoretical study of an atmosphere in radiative convective equilibrium with a given distribution of absolute and relative humidity has been computed by Manabe and Wetherald (1967) at the Geophysical Fluid Dynamics Laboratory (GFDL) as the asymptotic state of an initial value problem. They found that an atmosphere in radiative equilibrium requires a convective adjustment to approximate the upward transfer of heat by atmospheric motions. Their study of the thermoequilibrium of the atmosphere investigated the role of various atmospheric absorbers in maintaining the existing thermal structure of the atmosphere and of the observed climate of the earth's surface. In addition, Manabe and Wetherald have considered the effect of many influences on temperature variation in the atmosphere. I will consider here only their conclusion regarding CO_2. They assumed that the mixing ratio in the atmosphere is constant with altitude, it was 0.0456% by weight or 300 p.p.m.. Their results showed the vertical distributions of equilibrium temperature corresponding to three different CO_2 concentrations by volume. They also found that the larger mixing ratio of CO_2 occurs with higher equilibrium temperature of the earth's surface. The larger the mixing ratio of CO_2, the colder will be the equilibrium temperature of the stratosphere. The temperature of the stratosphere depends much more on CO_2 content than does that of the troposphere. They report that a doubling of the atmospheric CO_2 could increase the surface temperature by 2.3°C for a realistic distribution of relative humidity. Recent modeling approaches using the

Goddard Institute for Space Studies (GISS) model (Hanson et al, 1984), seem to indicate that there is a more general warming to be expected during the winter months with the variation of the climate under the CO_2 influence.

Elsaesser in 1984 stated that most climate models are lacking in relevance due to the fact that they have not been developed with the ocean surface temperature as a fundamental variable. He suggests that if the ocean surface temperature is a control variable the atmospheric sensitivity is considerably reduced. He uses paleoclimate data to support this fact. One thing that is clear from the many research workers in the field is that there is no one model of CO_2 impact on climate that is acceptable to all.

1.4 A Recent Trend

The possibility of a global warming induced by increasing levels of atmospheric carbon dioxide has led to increased interest in monitoring global temperatures. A study of temperature change in polar regions was reported by several researchers (Raper et al. 1983). Polar stations surface-air temperature data was analysed to produce a time series of temperatures on a regional basis. Changes in the Arctic temperatures since about 1966 and in Antarctic temperatures since 1960 showed significant warming trends. In addition, for the period 1975 to 1982 there was a high positive correlation between temperature variation in the Arctic and Antarctic. A long-term cooling trend which began in about 1940 in the Arctic continued from the mid-1950's to the mid-1960's. The mid-1960's marked the turning point between cooling and warming trends. From the mid-1960's to 1982 the Arctic series had a warming trend with a linear rise of $0.035°C\ year^{-1}$.

In this analysis the major objective was the identification of a temperature trend using data collected at a single weather station. The Climatological Reference Station (CRS) of the Saskatchewan Research Council has over 20 years of continuous record. It was thought of interest at this time to examine the mean annual and monthly mean temperature data taken at this location to identify possible trends.

2. PROCEDURES

The Climatological Reference Station (CRS) is located on the University of Saskatchewan grounds, in a surrounding of primarily agricultural fields, and approximately 5 km from any major urban activity. Climatic data consisting of air temperature, precipitation, soil temperature, evaporation, wind speed, bright sunshine, humidity, and solar radiation are recorded at the CRS, with continuous daily observations. A climatic data summary (Wheaton et al. 1984-A) was provided most recently for the year 1983. In most single station climate analysis the recording process can be interrupted and data generated can represent two quite distinct populations. This can occur, for example, when the site of recording station is modified either by being relocated or by the construction of buildings in the vicinity or even by change of instrumentation used. In the case of the CRS data used in this report none of these changes has occurred. It was felt that the data set from which this report was produced does not suffer from any of the above shortcomings. The fact that the records from this station represent a consistent data set through the two decades makes it particularly well suited for analysis to identify trends. Standard observation procedures as outlined by the Atmospheric Environment Service have been in practice since its inception. Daily mean temperature is determined as a simple average of the daily maximum and minimum readings. The monthly average is calculated by averaging the monthly mean maximum and the monthly mean minimum temperatures. The annual average is the mean of the mean monthly values.

The estimation of trend (Spiegel, 1961) can be achieved in several possible ways. They are:

1. The freehand method which consists of fitting a curve simply by looking at the graph.

2. The moving average method can be used to eliminate cyclical or seasonal patterns to show only the trend.

3. The method of "semi-averages" consists of separating data into two roughly equal parts and averaging the data in each part. A trend line is then drawn between these two points. The significance of these two values is normally determined with a student's t test.

4. The method of least squares can be used to find the equation of the appropriate trend line. Then trend values are computed.

All of these methods were applied to the twenty years of record which we have at CRS in an attempt to show if there was an identifiable trend in the temperature.

3. RESULTS

The record of 20 years of observation for mean annual temperature is shown in Table 1, details of the monthly values are shown in the Appendix. The 20-year mean annual temperature is 1.6°C, with both the highest and the lowest mean annual temperatures occurring only recently in the record. The lowest value during the period of record is 0.4°C in 1982. The highest value is 4.5°C in 1981. Figure 1 shows a graphical plot of the information presented in Table 1.

Table 1. Mean annual temperature for 20 years of record at CRS.

Year	T (°C)	Year	T (°C)
1964	2.7	1974	1.2
1965	0.5	1975	0.9
1966	0.5	1976	3.0
1967	1.2	1977	2.6
1968	2.2	1978	1.4
1969	1.1	1979	0.6
1970	1.7	1980	2.4
1971	1.2	1981	4.5
1972	0.6	1982	0.4
1973	2.0	1983	2.1

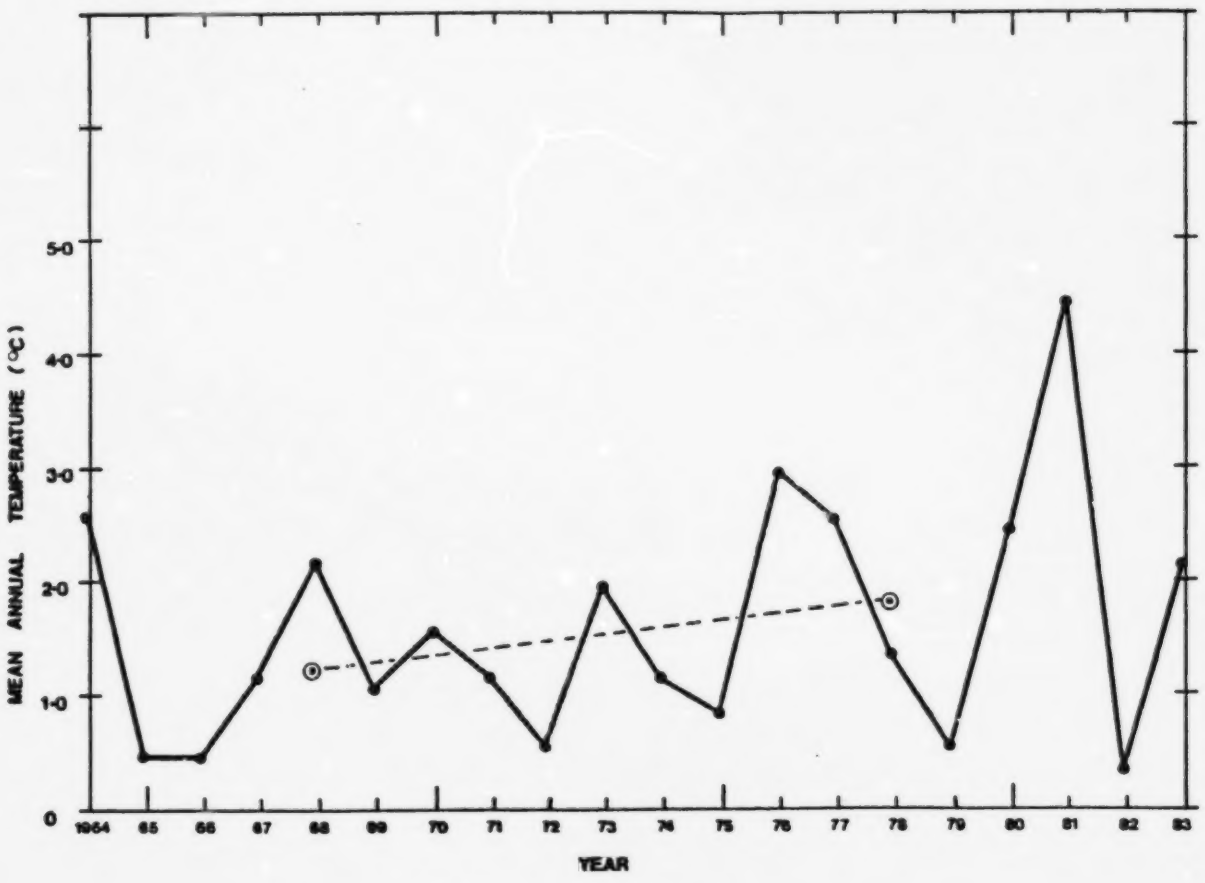

Figure 1. Mean annual temperature vs year. The dashed curve is the semi-averaged line.

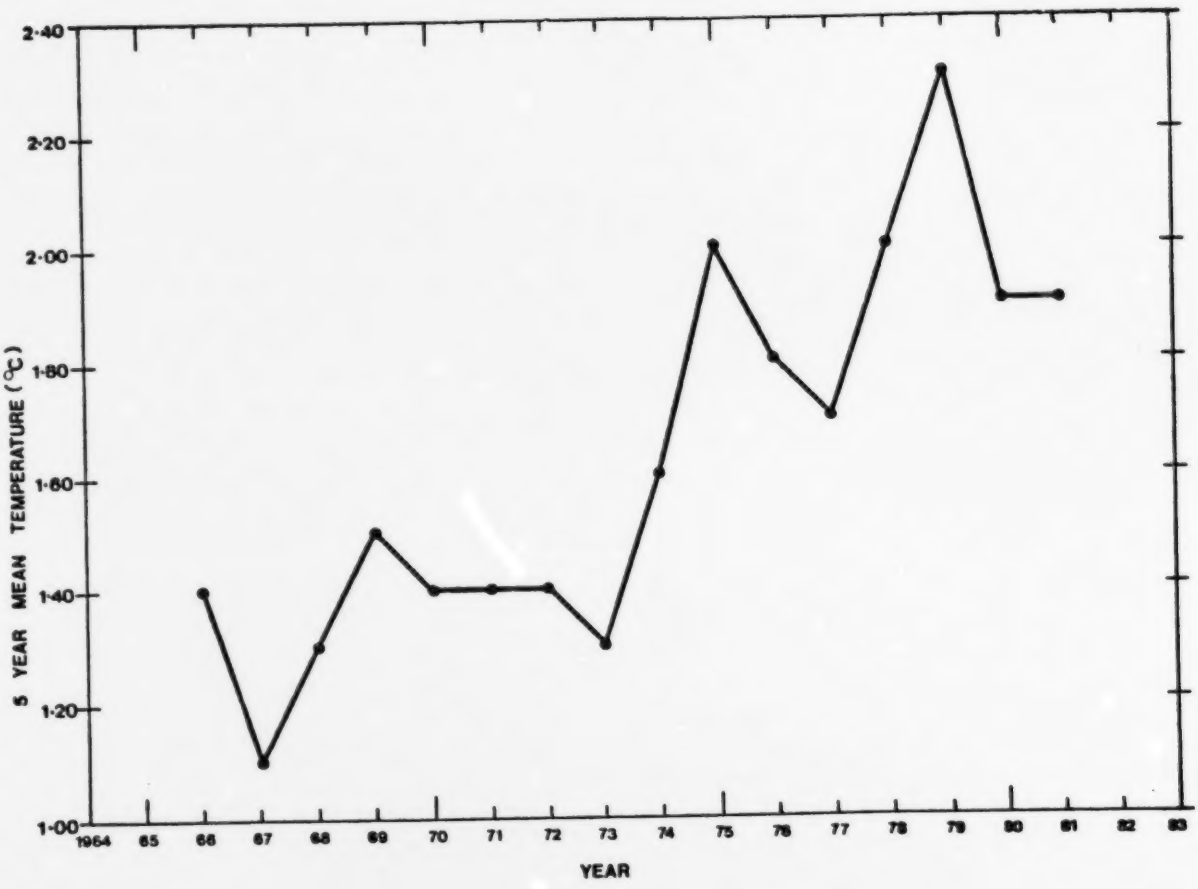

Figure 2. Five-year running means for the annual temperature at the CRS.

The general impression derived from this figure is that there appears to be an increase in mean annual temperature. However, this effect is clearly masked by the inherent variability of the data. By using the moving average technique it was possible to smooth the data series. Figure 2 shows a graphical plot of the 5-year running means for the data on Table 1. This graph is much easier to interpret for trends than that of the simple annual means. By smoothing the data in this way a clearer view of the warming trend is seen. There seem to be two distinct periods with the years 1974-75 marking a transition.

Another method uses the semi-average data. These values are derived by finding the mean value for the first half of the period (1964-1973) and that for the second half (1974-1983). The two values are plotted on the graph of Figure 1 and connected by a line. This semi-average line again indicates an upward trend in the second half of the data period. More details of this trend are shown in Table 2 where the mean temperature values for each month were divided into the two decades. The means for each of the decades are shown. In nine of the twelve months the temperature of the decade means showed an increase in air temperature. January was the month that showed the largest increase of temperature, 2.1°C. There were two months which showed a decrease in the decade semi-averaged temperature, with the largest range of 0.8°C for the month of August. On a mean monthly basis, analysis of the air temperature data for the period of record reveals that the summers are marginally cooling while the winters are warming significantly. The winter warming effect appears far larger than the summer cooling period.

Table 2. Semi-averaged mean monthly temperature data from CRS for the 1964 to 1983 period.

Month	Temperature (°C)		ΔT(°C)
	1964-73 A	1974-83* B	B-A
January	-20.0	-17.9	2.1
February	-14.6	-12.9	1.7
March	- 8.4	- 7.6	0.8
April	3.0	4.2	1.2
May	11.3	10.9	-0.4
June	15.6	15.6	0
July	18.0	18.8	0.8
August	17.8	17.0	-0.8
September	11.2	11.6	0.4
October	4.6	5.2	0.6
November	- 6.5	- 4.9	1.6
December	-15.6	-14.5	1.1

* 1984 is included in the months January to August.

Statistical tests can be applied to this data to find out if the difference between the means of this data is significant. The student's t test was applied to the data for this purpose (Miller and Freund, 1965). Table 3 is a summary of the annual decade means, standard deviations and calculated student's t statistic. At the ten percent probability level the value of t is 1.328 and at the five percent probability level t is 1.729 for 19 degrees of freedom. Since the calculated t is not greater than this, there is no statistical difference between the decade annual mean temperatures or the winter month temperatures for the years 1964-73 and 1974-83 by this method of analysis.

Table 3. Mean temperatures, standard deviations and the calculated student's t statistic for several periods between the two decades of record.

	1964-1973		1974-1983		
	Mean (°C)	Standard Deviation	Mean (°C)	Standard Deviation	t (Calculated)
Annual	1.4	0.7	1.9	1.3	1.0
January	-20.0	5.0	-17.9	5.2	1.0
February	-14.6	3.7	-12.9	5.7	0.8
November	-6.5	3.6	-4.9	3.2	1.3
December	-15.6	3.3	-14.5	4.4	0.6

The method of least squares can be used to determine a trend line in the annual data by assigning for each year a number which successively increments by one. For example, 1964 is assigned the value 0 and 1965 is assigned the value 1, etc. The equation of the trend line from this

method (Spiegel, 1961) is $y = 1.149 + 0.052 x$ where y is the predicted annual mean temperature and x is the year from the base year. A positive correlation exists between year and temperature with increases of 0.052 °C/year. This can be compared with the Arctic where from the mid-1960's to 1982 there has been a warming trend with a linear increase of 0.035 °C/year.

In summary, while most methods seem to show a temperature increase during the period 1964 to 1983 at CRS, it seems that due to the inherent variability, trends can only be estimated in the broadest terms.

4. DISCUSSION

4.1 The Atmospheric Carbon Dioxide Effect

We have seen that CO_2 is an important part of the carbon cycle and that CO_2 in nature exists in a balance. The CO_2 exchange between the atmosphere and the biosphere is very intense. It is based on two main living processes of organisms: assimilation (for autotrophic green plants) and respiration (for all organisms). The intensity of this interchange between atmosphere and biosphere depends on the environmental conditions of the plants.

It has been shown that the CO_2 content in the atmosphere is steadily increasing, probably largely due to industrial sources located in mid-latitudes of the northern hemisphere. The oceans, although representing an enormous sink for the CO_2, are relatively ineffective due to a very slow vertical circulation.

The changes of CO_2 are often assumed to be causes of climatic change because its effect on long-wave radiation is understood. It is, however, much more difficult to interpret its meteorological meaning and its effects. CO_2 is only one of the elements of the radiation balance of the earth whose secular variation is known. Cloudiness, water vapour and temperature are others and they show strong variations with the day, season and latitude, however the observations are so scant over about 60% of the earth's surface that a secular variation in these factors cannot be recognized.

The importance of carbon dioxide to the climate of the earth is just beginning to be realized by the broad mass of the scientific community. Many of the pioneers have suggested that regular and systematic

observations should be extended over much more of the earth's surface, and more frequent and more reliable methods of carbon dioxide monitoring would be desirable.

4.2 Climate Trends at CRS

In this analysis the major concern was with the identification of a temperature trend using mean annual temperature data from a single weather observing station. A warming trend has been indicated by the use of several methods. The freehand method of determining temperature trends seems to have worked well, revealing an increase of temperature. The moving averages method, when applied to the data, seemed to show two distinct temperature regimes with the later period being warmer and the transition in temperature occurring about 1975. Some authors (Spiegel, 1961) have cautioned however, that moving averages may generate cycles which are not present in the original data. Also, moving averages tend to be affected by extremes. It is noteworthy to see that a more detailed look at the twenty-year monthly trend of semi-averaged means does show that nine of the twelve months indicate a warming trend in progress. Although this trend at the Saskatchewan Research Council's CRS appears not to be statistically significant when considered in isolation, it is in line with other evidence of a warming trend for the Northern Hemisphere as described by Jones et al. 1982, and for the Arctic as described by Kelly et al. 1982. In addition, it is interesting to note that preliminary work done on the normals for Saskatchewan (Wheaton, 1984-B) show that this pattern of temperature change may be occurring quite generally throughout the province, with the decade of the '70's being warmer than the decade of the '40's.

The coolest year of our record was 1982. It was in that year that a relatively small but sulphur-rich eruption of the El Chichon volcano of Mexico injected into the stratosphere a fine dust of sulfuric acid droplets (Wendler, 1984) denser than any volcanic cloud since 1883. A possible contributing factor to the relative coolness may be the stratospheric dust and aerosol loading caused by the eruption of this volcano.

The warmth of 1981 in our records is remarkable. It is largely the result of a very mild winter in 1981. Many other authors (Raper et al. 1982, Kelly et al. 1982) have studied temperature trends in Arctic regions and record similar events. One can only speculate at this time that some unusual event (such as a warming of ocean waters) may have affected the trend. However, at this point further analysis is required. Although the recent warming effect seems to be consistent with the hyopthesized effects of increasing carbon dioxide (NRC(US)1982), the duration and magnitude of this trend is insufficient to provide an independent verification. Most authors (Bryson, 1974) feel that 30 years of record is about the minimum for trend analysis. It is felt, however, that continued monitoring of temperatures at the Saskatchewan Research Council's Climatological Reference Station will provide a clear indication of large scale climatic change in this important agricultural area of Canada. If a warming trend is confirmed at some point in the future, it could very well be attributed to a natural secular variation of the atmosphere's climate cycle. This report is simply a first indication that a change is taking place in our climate and that atmospheric carbon dioxide has a possible impact.

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APPENDIX

A complete data set of mean monthly air temperatures taken for the period of interest at the Climatological Research Reference Station (CRS) of the Saskatchewan Research Council.

MONTHLY MEAN TEMPERATURES FROM THE SASKATCHEWAN RESEARCH COUNCIL FOR THE PERIOD OF THIS STUDY

YEAR	January	February	March	April	May	June	July	August	September	October	November	December	MEAN
1964	-18.0	-6.9	-11.2	5.1	12.6	15.9	20.6	16.7	9.6	6.7	-5.3	-19.9	2.7
1965	-20.3	-18.1	-13.3	2.3	10.4	15.6	18.5	17.8	6.C	7.3	-9.6	-11.8	0.5
1966	-26.1	-17.2	-6.2	1.1	11.5	14.2	18.4	16.6	14.1	4.3	-11.7	-13.3	0.5
1967	-18.4	-16.5	-11.7	-1.9	9.9	14.2	18.6	17.9	15.6	3.9	-4.2	-13.5	1.2
1968	-18.3	-12.8	-1.7	3.7	9.8	15.2	17.2	14.3	11.6	4.8	-2.1	-15.9	2.2
1969	-27.8	-15.1	-10.1	6.3	10.6	13.7	17.2	19.3	12.1	0.7	-3.6	-10.0	1.1
1970	-19.2	-12.8	-12.1	3.0	10.8	18.7	20.0	18.6	12.5	5.6	-2.6	-19.3	1.7
1971	-22.8	-12.7	-9.2	3.3	12.8	15.3	16.4	19.2	11.1	4.5	-5.4	-17.7	1.3
1972	-22.3	-20.1	-7.1	4.3	12.9	17.7	15.6	19.1	8.1	2.2	-4.5	-18.4	0.6
1973	-13.2	-13.9	-1.5	2.3	11.8	15.2	17.4	18.3	10.9	5.6	-12.5	-16.4	2.0
Mean	-20.0	-14.6	-8.4	3.0	11.3	15.6	18.0	17.8	11.2	4.8	-6.5	-15.6	1.4
1974	-22.4	-13.8	-12.9	2.4	7.8	15.7	18.1	14.3	9.1	6.7	-3.2	-6.9	1.2
1975	-15.3	-17.5	-13.0	-0.1	10.0	14.8	19.9	14.7	11.7	4.3	-4.7	-14.1	0.9
1976	-14.3	-9.5	-8.9	7.1	12.5	15.0	18.3	18.3	13.4	3.0	-5.6	-13.3	3.0
1977	-19.8	-6.2	-2.7	7.5	13.9	16.4	17.8	13.4	10.7	6.1	-7.0	-19.3	3.6
1978	-23.3	-16.3	-5.2	4.3	12.6	17.1	17.8	16.0	11.9	6.4	-3.1	-16.0	1.4
1979	-21.0	-24.2	-8 5	-2.3	8.8	15.2	19.4	17.1	13.2	5.6	-4.9	-11.4	0.6
1980	-18.4	-13.8	-9.9	8.9	14.0	15.5	18.5	16.0	11.0	6.0	-2.5	-16.5	2.4
1981	-10.4	-10.5	-1.5	5.5	12.5	15.0	19.0	20.5	13.5	3.0	0.5	-13.0	4.5
1982	-26.5	-16.0	-8.0	2.0	9.5	13.5	17.5	16.0	11.0	5.5	-10.0	-11.7	0.4
1983	-13.0	-10.0	-7.0	3.0	8.5	15.5	19.0	20.0	10.0	5.3	-8.9	-22.9	2.1
1984	-12.4	-3.9	-5.5	7.4	10.1	16.1	21.7	20.3					
Mean	-17.9	-12.9	-7.6	4.2	10.9	15.6	18.8	17.0	11.6	5.2	-4.9	-14.5	1.9
											Twenty year mean		1.6